Airbus wake vortex flight test campaigns and general conclusions

Paris, January 9th, 2009
WakeNet3-Europe Workshop on
Wake Turbulence Safety in Future Aircraft Operations
Wake Vortex Studies by Airbus
- Vortex Measurements
- Wake Encounter Simulation, Severity and Risk
- Wake Encounter Flight Tests
- Wake Encounter Incident Analysis & Wake Alerting

Airbus Wake Encounter Flight Tests
- Encounter Flight Test Methodology
- Evaluating Wake Encounter Flight Tests

Conclusions
- A380 Wake Vortex
- Recategorisation
Airbus has conducted a large number of real-life wake vortex measurements

- **Ground-based pulsed LiDAR**
  - Individual aircraft
    - Frankfurt airport in 2004
  - Back-to-back measurements
    - Multiple sites, during 2005 - 2007
    - Airbus A380, A340, Boeing B747, B777
    - Approach, Holding and Take-off
    - 627 LiDAR runs

- **Airborne LiDAR (by DLR)**
  - Several measurements during cruise flight wake encounter tests.

Measuring vortex physics, decay and transport under real-life circumstances
Airbus - with research partners - has set-up a dedicated 6-DOF wake encounter simulation capability

- Vortex Encounter Severity Assessment - VESA Tool
  - Fast-time wake encounter simulation capability for
    - Identification of worst case encounter scenarios
    - Monte Carlo Simulation capability
    - Risk assessment in combination with airspace and vortex simulation (e.g. WakeScene tool by DLR)

Understanding aircraft reactions to vortex encounter and the overall wake encounter risk
Wake Encounter Flight Tests

Airbus has engaged in the most extensive wake encounter flight test campaign ever conducted.

- Total number of individual wake encounters: 1,041
  - 167 wake encounters at cruise
  - 874 wake encounters during approach
  - Multiple follower aircraft, including A318, A320, A300, A380

- New testing techniques and support (e.g. oil-spray system)

Probing aircraft reactions to vortex encounter under real-life circumstances
Airbus regularly evaluates occurrences of wake encounter incidents that involve Airbus aircraft.

Reported wake encounter incidents are evaluated with regard to:
- Likely encounter geometry
- Influence of vortex, flight control system and piloting

General conclusion
- In most situations, the flight control system (F/CTL) and Autopilot are well capable to counter the wake impact
- The AP should remain connected during a wake encounter
  - „keep hands-off“
Airbus supports and is engaged in European research projects developing new technologies to reduce the number of wake encounters and to increase capacity.

- **I-WAKE**
  - Development of on-board wake alerting system based on forward-looking sensors

- **AWIATOR**
  - Flight testing of airborne, forward-looking UV LiDAR

- **FLYSAFE**
  - Continued development of on-board wake alerting systems based on sensors and probabilistic prediction models including the cruise flight phase

Evaluating methods to decrease the probability of wake encounters
Content

Wake Vortex Studies by Airbus
- Vortex Measurements
- Wake Encounter Simulation, Severity and Risk
- Wake Encounter Flight Tests
- Wake Encounter Incident Analysis & Wake Alerting

Airbus Wake Encounter Flight Tests
- A380 Wake Encounter Risk Assessment
- Evaluating Wake Encounter Flight Tests

Conclusions
- A380 Wake Vortex
- Recategorisation
To support safe and efficient A380 operations, Airbus engaged in the most extensive wake encounter (WVE) risk assessment ever conducted.

In agreement with the international working group, the A380 is assessed versus existing Heavy aircraft serving as reference in a relative safety assessment.

Airbus believes that wake encounter flight tests are the ultimative method for this assessment and that they are also required for validation of recategorisation methods.
From wake generator to encounter severity ... 
... a complex process chain

- **Wake creation**
- **Wake evolution**
- **Wake encounter**
- **Aircraft reaction**
- **Encounter hazard**

Relative Safety Assessment:
- Equal or less risk (severity) behind A380 and Reference A/C at defined separation distances

© AIRBUS S.A.S. All rights reserved. Confidential and proprietary document.
A380 Wake Encounter Risk Assessment

From wake generator to encounter severity ...
... with many influences

- Air speed
- Configuration
- Altitude ...
- Atmospheric turbulence
- Stratification
- Height above ground ...
- Encounter geometry
- Follower A/C size
- Wake / aircraft interaction ...
- Follower A/C control system
- Pilot / AP reaction ...
- Follower A/C operational conditions ...

Wake creation

Wake generator A/C

Initial, rolled-up wake

Wake evolution

Evolved & aged wake

Wake encounter

Wake impact on follower A/C

Aircraft reaction

Follower A/C reaction

Encounter hazard

Hazard of ensuing situation
From wake generator to encounter severity ... ... and different measurement options

Circulation may be the single most influential wake characteristic related to encounter severity but it is by far not the only one!

Other relevant characteristics include: core radii, tangential velocity distribution, spacing, bending
A380 Wake Encounter Risk Assessment

From wake generator to encounter severity ...
... and different measurement options

Wake generation

Initial, rolled-up wake

Evolved & aged wake

Wake encounter

Remote measurement (LiDAR)

Wake creation

Wake evolution

Only wake encounter flight tests allow to evaluate all effects of the specific aircraft wake on a follower aircraft!

All wake characteristics are inherently included.

Remote measurement (LiDAR)

Wake impact on follower A/C

Aircraft reaction

Follower A/C reaction

Encounter hazard

Hazard of ensuing situation

Different measurement techniques:
(1) In-situ measurement of vortex characteristics
(2) Wake-induced forces & moments (wake impact)
(3) Characterisation of aircraft reaction
(4) Characterisation of encounter severity

Wake Encounter Flight Test
(1) In-situ measurement of vortex characteristics

Pros: - direct flow field measurement
- identifies flight path through wake

Challenges: - needs high-quality sensors
Evaluating Wake Encounter Flight Tests

(2) Identification of wake impact on encountering A/C

- Determination of wake-induced forces & moments acting upon the A/C during the encounter.
- Based on knowledge of total aircraft dynamics in calm atmosphere (aircraft aerodynamic simulation model).

Pros:
- Direct measure of wake impact
- Independent from aircraft and pilot reaction

Challenges:
- Needs validated aircraft aerodynamic simulation
Evaluating Wake Encounter Flight Tests

(3) Characterisation of aircraft reaction
   E.g. maxima of aircraft attitudes, rates, accelerations

(4) Characterisation of encounter severity
   Compound severity metrics containing, for example, weighted aircraft upsets and subjective evaluations

Pros: - closest measures of operationally relevant severity

Cons: - strongly influenced by external factors independent of the wake generating aircraft
       - thus larger scatter in the test results that is hiding the pure wake impact
Evaluating Wake Encounter Flight Tests

- Wake Encounter Flight Tests better reflect severity than LiDAR measurements
  - Only flight tests measure the real and full wake impact on an encountering aircraft

- Evaluation of WVE flight test comes with its own challenges
  - New evaluation methodologies
  - Control and consideration of external influences and variations
  - ... but when evaluating the direct wake-impact the number of external influences is reduced and the statistical significance is increased

- Airbus analysis of WVE data indicates that today’s A380 separations are still too conservative for Heavy and Medium followers
Content

Wake Vortex Studies by Airbus
- Vortex Measurements
- Wake Encounter Simulation, Severity and Risk
- Wake Encounter Flight Tests
- Wake Encounter Incident Analysis & Wake Alerting

Airbus Wake Encounter Flight Tests
- Encounter Flight Test Methodology
- Evaluating Wake Encounter Flight Tests

Conclusions
- A380 Wake Vortex
- Recategorisation
Conclusions (1)

- The A380 wake vortex flight test campaign is an unprecedented effort with more than 300 flight tests hours, more than 600 Lidar runs and close to 1050 wake encounters.

- A lot of new flight test techniques had to be developed and validated:
  - For Lidar runs
  - For cruise encounters at high altitude
  - For encounters in approach.

- Analysis of data involved an international team of experts in the Working Group.

- All results based on Lidar tests and encounters in cruise have been used for the last ICAO State Letter.
Today, the situation is that a Light has to be at 6 NM behind a B747, and the B747 has to fly at 6 NM behind the A380!

All the encounter tests performed in approach have been analyzed by Airbus and the conclusion, based on results and common sense, is that there should be no penalty for Heavies and Mediums. Airbus also believes that 6 NM separation of Light behind Heavy is unsafe and has decided to keep 8 NM for the A380.

Today, decision has been made to continue work on use of the Airbus encounters.
AIRBUS is strongly supporting the RECAT program.

However, AIRBUS believes that RECAT cannot rely only on “paper aircraft” and computations without any validation by physical demonstration. This would be at the opposite of all standard practices in the industry.

Such an attitude would also weaken the RECAT group position.

Today there is a huge data base obtained by Airbus tests which could be used for validation of some aircraft models.
THANKS
© AIRBUS FRANCE S.A.S. All rights reserved. Confidential and proprietary document.

This document and all information contained herein is the sole property of AIRBUS FRANCE S.A.S. No intellectual property rights are granted by the delivery of this document or the disclosure of its content. This document shall not be reproduced or disclosed to a third party without the express written consent of AIRBUS FRANCE S.A.S. This document and its content shall not be used for any purpose other than that for which it is supplied.

The statements made herein do not constitute an offer. They are based on the mentioned assumptions and are expressed in good faith. Where the supporting grounds for these statements are not shown, AIRBUS FRANCE S.A.S. will be pleased to explain the basis thereof.